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*A drying installation
on an Illinois farm*



EFFECT OF DRYING TEMPERATURE ON QUALITY OF WHEAT

By J. H. RAMSER, Associate in Agricultural Engineering¹

BEFORE COMBINED WHEAT can be stored safely, it is often necessary to dry it artificially. It is frequently desirable to make use of heated air as the medium for rapid drying, even though high drying temperatures are known to affect the quality of some farm grains for commercial processes. Since little specific information has been published concerning the effect of drying temperatures on the milling and baking qualities of wheat, an experiment was set up at the Illinois Agricultural Experiment Station in the summer of 1952 to investigate the effect of various drying conditions on the quality of Illinois soft and hard winter wheat. Winter wheats were used in these tests because they are most widely grown in the state.

The wheat varieties chosen were Illinois No. 2 and Westar. Illinois No. 2 is a soft variety not particularly well adapted to Illinois, but a number of its selections and crosses are being grown extensively in the state. Westar is a hard variety with a record of high yields and is adapted to central and northern Illinois.

Drying Temperatures and Humidity

Wheat of these two varieties was harvested with a combine when the grain moisture was approximately 20 percent. This moisture content is too high for storage in a tight bin without spoilage. The grain was held under refrigeration at 35° F. until the various lots could be dried. Moisture content was determined with a Brown-Duvel moisture tester and checked in an electric drying oven. The air temperatures used in drying the grain were held as closely as possible to 130, 140, 160, 180, and 200° F. Relative humidity was maintained at 10 percent or above for all drying.

Samples of each variety were allowed to dry in natural air to

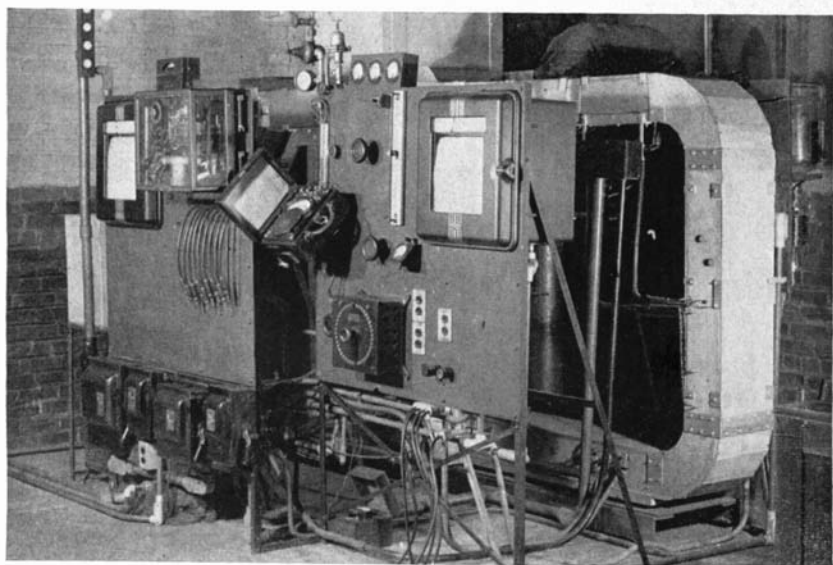
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serve as standards of comparison for the milling and baking qualities of the artificially dried wheat. These samples, designated as Control 1 and Control 2, of Illinois No. 2 and Westar varieties respectively, were dried in air varying in temperature in the range of 75° to 90° F. The relative humidity varied from 50 to 60 percent.

The original and final moisture content of the wheat samples, the time, and the drying conditions employed are given in Table 1.

Drying Equipment

The wheat samples were dried in a laboratory drier (Fig. 1) in the Department of Agricultural Engineering at the University of Illinois. The drying apparatus consisted of a closed duct through which the drying air was circulated by a centrifugal blower. That portion of the duct in which the wheat was placed consisted of a vertical section with inside dimensions of 19 by 19 inches. A smaller duct with inside dimensions of 6 by 10 inches was joined to the vertical section above and below the position of the wheat sample to be dried to complete the drying air circuit. The blower connections were made in the smaller section of the air duct. A 20-pound sample



The laboratory drier used in the tests. (Fig. 1)

Table 1.—Results of Wheat Milling and Baking Tests

Sample No.	Initial moisture ^a	Final moisture ^a	Drying temperature	Relative humidity	Drying time	Pebling index	Particle size	Break flour yield	Flour yield	Mixogram area (9% protein)	Cookie diameter	Loaf volume (9% protein)
	perct.	perct.	°F.	perct.	hours	perct.	perct.	perct.	perct.	sq. cm.	cm. X 2	cc.
Illinois No. 2 Soft Winter Wheat												
1.....	18.6	12.4	200.6	10	.94	53.6	18.9	22.7	75.6	48	17.3	527
3.....	22.2	12.5	179.4	10	.88	55.4	20.0	24.4	75.8	50	17.3	572
4.....	21.4	12.0	160.0	10	1.50	57.4	20.9	26.0	75.8	53	17.2	602
5.....	20.6	14.0	139.6	14	1.50	51.8	20.8	24.8	75.7	54	17.4	613
6.....	19.2	11.6	129.6	19	2.00	48.5	20.4	25.3	75.5	57	17.2	661
Control 1.....	18.6	12.8	Air	Air	528	45.3	18.3	22.7	74.8	56	17.2	608
Westar Hard Winter Wheat												
2.....	19.3	12.0	199.0	11	.97	42.6	10.3	16.1	77.3	62	16.3	569
7.....	19.4	9.3	178.2	11	1.25	41.8	10.8	16.2	77.1	76	16.6	618
8.....	19.6	12.6	158.3	13	1.25	40.3	10.1	15.4	76.6	79	16.4	671
9.....	20.0	14.2	140.8	17	1.25	41.0	10.1	14.9	76.0	80	16.5	674
10.....	19.4	13.8	130.0	22.5	1.60	38.5	10.1	14.8	76.3	84	16.4	668
Control 2.....	19.3	13.4	Air	Air	456	34.0	9.0	13.9	76.0	81	16.2	647
Least significant difference ^b					1.5	.7		2.1	2.5	1.9	.3	38

^a All moisture tests on wet basis.^b Significance calculated at the 5-percent level.

of wheat was carried in a tray suspended from the platform of a Toledo scale so that the weight of the sample could be obtained at any time during the test. The tray sides were solid, and the bottom was of small-mesh screen.

To obtain accurate temperature and relative-humidity readings of the drying air, a thermocouple probe was held at the center of twelve equal areas of the duct cross-section in a plane immediately before the drying air came in contact with the wheat sample. The probe carried two thermocouples, one for the dry-bulb temperature, the other, kept wet by a tube from a water reservoir, for the wet-bulb temperature. These readings were used to set two recording thermocouple potentiometers: one for the dry-bulb temperature and the other for the wet-bulb temperature. From these two temperatures the relative humidity was determined for each area and the average computed.

The circulating air was heated by electric resistance elements, one of which was controlled by a recording potentiometer to maintain the desired dry-bulb temperature. The duct material was asbestos-cement board through which moisture-laden air passed to some extent. Since in some tests the loss of moisture from the duct was greater than the amount given up by the wheat, water vapor was added to the circulating air in those tests by means of a steam jet to maintain the relative humidity above a minimum of 10 percent.

Air velocity was measured by a conventional Thomas meter. With this instrument the air flow is determined by the electrical energy required to heat the flowing air a certain number of degrees. The air flow was maintained very nearly the same in all tests, approximately 300 feet per minute.

Quality Tests

Tests were made of each wheat sample at the Soft Wheat Quality Laboratory, U. S. Department of Agriculture, Wooster, Ohio, to determine the effect of drying conditions on the milling and baking qualities. The following tests were used to determine these qualities:

1. **Pearling index** — the percentage loss in weight of a wheat sample when subjected in a barley pearler to the abrasive action of a carborundum wheel for 60 seconds. It is a measure of kernel texture or hardness, higher indexes indicating softer kernels.

2. Particle-size index. This index gives an indication of the granulating properties of a wheat sample, and is obtained by rotapping through a nest of sieves for 5 minutes the sample ground at a uniform setting in a standard Labconco mill. The weight of fine flour expressed as percentage of the original sample is the particle-size index. Softer-textured wheats granulate more finely than harder ones, hence have higher particle-size indexes.

3. Break flour yield. The amount of flour produced in the break section (corrugated rolls) in the normal experimental milling operation is an indication of the wheat-fracturing characteristics. Wheats of softer kernel texture fracture more finely and yield larger quantities of break flour. The weight of this flour, expressed in percent of the wheat milled, is reported as break flour yield.

4. Flour yield — the percent of straight grade flour produced from a given weight of wheat tempered to the proper moisture content for the experimental milling operation. Flour yields thus obtained are directly related to those obtainable in commercial milling.

5. Mixogram area. This is the area in square centimeters under a mixograph curve for a mixing time of seven minutes when produced on a National Swanson Working instrument. Greater mixogram areas at a uniform 9-percent protein level are associated with greater gluten quality.

6. Cookie diameter — a measure of the potentialities of a flour for cookie production. The average diameter of two cookies made from 40 grams of flour by a micro method is given as the cookie diameter. Cookies of greater diameter are usually produced from the weakest soft wheat varieties.

7. Loaf volume. Data for loaf volume are obtained when using a rich, highly bromated experimental baking formula. Larger loaf volumes at a uniform 9-percent protein level show stronger gluten.

Results of Illinois No. 2 Soft Wheat Milling and Baking Tests

The results of the quality tests made on the artificially dried samples of Illinois No. 2 soft winter wheat are given in Table 1.

The pearling index of the artificially dried samples was signifi-

cantly higher at all temperatures than that of the air-dried sample. These higher values indicate a softer kernel texture, probably not very desirable for the softest wheat types.

In break flour yield the values at all drying temperatures except 200.6° and 179.4° were significantly higher than that of the naturally dried sample. These results indicate that drying causes a tendency toward easier and finer fracturing of the kernel. The same effect was shown in the test for particle size. This increase in fineness of granulation may be undesirable under certain commercial milling conditions.

Although the flour yields of all artificially dried samples were greater than those of the air-dried control, the differences were not significant.

The mixogram-area data for the artificially dried samples were significantly lower than those of the air-dried sample at all temperatures except 129.6°. Lower area (adjusted to a uniform 9-percent protein level) indicates weaker gluten.

The cookie diameter was not significantly different for any of the treatments. This indicates that the value for cookie production, which is important for soft wheat flour, was not impaired by the drying temperatures used.

The loaf volume, based on 9-percent protein content, was significantly lower than that of the air-dried sample only for the sample dried at a temperature of 200.6° F. although the volume for the sample dried at 179.4° neared significance. This indicates that a drying temperature of 180° or above may adversely affect the bread volume. This fact may not be too important since soft wheat flour is not widely used for bread making.

Results of Westar Hard Wheat Milling and Baking Tests

The results of the tests with Westar are also given in Table 1.

The pearling indexes were significantly higher for all artificially dried samples than for the air-dried sample, indicating that the kernel characteristics of the wheat were altered by the drying process. While the flour yield for the artificially dried samples was equal to or higher than that of the air-dried sample, none of the differences were statistically significant.

The values for break flour yield for the artificially dried samples were not significantly different from that of the air-dried sample except for drying temperatures of 178.2° and 199°. While the particle-size indexes were significantly greater for all artificially dried samples, the differences were not great. This slight increase in particle size probably would not be very important for hard wheat.

The mixogram-area data were not significantly lower for the artificially dried samples, except for those dried at 178.2° and 199°. This was taken to mean that the gluten was not altered except at the two highest temperatures used. At temperatures of 158.3° and below, the kernel softening, shown by the pearly index, probably did not change the gluten characteristics, important in hard wheat for bread making.

In cookie diameter only the samples dried at 140.8° and 178.2° differed significantly from the air-dried sample. Since hard wheat flour is not generally used for pastries, this difference is probably of little, if any, consequence.

The loaf volume, corrected to 9-percent protein, was significantly lower than that of the air-dried sample when a drying temperature of 199° was employed. This is an important test for hard wheat since much of this flour is used in bread making.

Drying Temperatures of 160° or Lower Recommended

These tests indicate that a drying temperature of approximately 160° F. or below for 1¼ to 1½ hours, or longer at the lower temperatures, does not materially affect the quality of the two varieties tested. Temperatures above 160° did show some lowering of the quality for both the hard and the soft wheat varieties.

It is recommended that those drying wheat, either for immediate sale or for storage, use drying air temperatures of 160° F. or below for the best possible quality.